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流域农业非点源污染多目标系统控制研究

Multi-objective System Control of Agricultural Non-point Source Pollution on Watershed Scale

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摘　要

农业非点源污染日益成为影响我国流域可持续发展的重要问题。对农业非点源污染只注重技术控制，不能适应我国流域经济发展与环境保护矛盾突出的国情。如何对流域农业非点源污染进行系统控制，具有重大的理论价值和实践意义。

本文以福建省九龙江流域为例，运用运筹学、经济学和系统工程学的一些基本理论，结合室内分析、现场调查、模型模拟等方法，研究了流域农业非点源污染控制的技术措施、经济手段和社会政策的优化设计，探讨了流域农业非点源污染的多目标系统控制机制，构建了评价流域农业非点源污染的指标体系，取得了如下成果：

第一、综合使用模拟模型 AGNPS5.0 和不确定性区间系统优化模型，进行控制农业非点源污染的最佳管理措施的优化设计，能够全面考虑流域环境、经济和技术等诸多因素的影响，这种设计过程和步骤具有较大的优势和科学性。

第二、将税收、补贴、保险、押金、基金等价格控制手段和排污权交易等数量控制手段运用于农业非点源污染控制领域，以汇水区为单位，系统构建了一系列控制农业非点源污染的环境经济手段及其求解模型，阐述综合经济手段和复合调控体系的控制机制，为我国环境经济政策的制定提供了方法和技术支持。

第三、在广泛调研的基础上，采用解释结构模型对政策控制九龙江流域农业非点源污染的系统进行辨识分析，得出影响流域农业非点源污染控制的最关键因素有气候、人口规模、农业政策、城乡二元结构、环境管理体制、相关法律体系建设等，分析了这些要素与农业非点源污染控制的关系，构建了政策体系。

第四、利用系统动力学的一般原理，解释九龙江流域农业非点源污染发生的动力、原因、控制方向，探讨了流域农业非点源污染系统控制所应考虑

的内容，提出制定最优控制策略的方法和步骤，研究构建了流域农业非点源污染的最优控制的动态运作机制。

第五、采用层次分析法科学构建了评价流域农业非点源污染的指标体系，并对五川流域和九龙江全流域农业非点源污染控制的效果进行了评价，得出全流域和小流域农业非点源污染控制状况均处于较差水平，但程度不同，这对实施流域综合管理具有一定的指导意义。

关键词：农业非点源污染；系统控制；最佳管理措施；环境经济政策

Abstract

Non-point source pollution has become an increasingly considerable problem which effects the sustainable development in agricultural watershed in China. The challenge of efficiently controlling agricultural non-point source pollution confronts many difficulties when only engineering and technical methods are implemented, regardless of outstanding conflict between economic development and environment protection in watersheds. The system control of agricultural non-point source pollution results in both theoretic value and significant realistic profit.

Operational Research, economics and engineering were adopted to study the systematic control of agricultural non-point source pollution in the Jiulong River Watershed, Fujian Province, southeast of China. Chemical analysis, locale surveys, model simulation and other methods were combined during the study. Optimal designs of technical practices, economic incentive system and policy system to control agricultural non-point source pollution in watershed scale were established and formulated detailedly according to the situation of the agricultural watershed. Multi-objective system control mechanism to reduce non-point source pollution was based on the optimal designs of all kinds of instruments. Indicator system to assess the impacts of pollution control was developed. Major endeavor and detailed results are as following.

(1) An optimal design of management practices to combine the simulation model of AGNPS 5.0 with the inexact interval system programming model to control agricultural non-point pollution in the Wuchan Catchment of Jiulong River Watershed, which could fully take account of watershed environment, economics, techniques and other factors scientifically.

(2) The prices control measures such as tax, subsidy, insurance, deposit, fund, and quantity control measures such as tradable emission permission, were put into practice. On the basis of catchment analysis, a series of economic incentive instruments and their optimal solving models were systemically developed to control agricultural non-point pollution. In addition, synthetical economic

measures and multiple regulation mechanism were also explained. The content mentioned above has brought forward methods and techniques for the establishment of environmental policies in China.

(3) On the basis of field studies in the entire watershed, Interpretive Structural Modeling (ISM) was adopted to carry out identified analysis on the system to control the non-point pollution in the Jiulong River Watershed. The most important key factors affecting agricultural non-point pollution control were identified including climate, the scale of agricultural population, agricultural policies, urban-rural dualistic structure, the system of environment management, and relative legislation systems, etc. In the end, the relationship between the affecting factors mentioned above and the agricultural non-point pollution was analyzed. Reforms of the policy systems are further discussed.

(4) The dynamics, causes and control difficulties of agricultural non-point source pollution in the Jiulong River Watershed were analyzed by applying the general principle of System Dynamics (SD). The context that should be considered in systemic control of agricultural non-point source pollution was discussed. The approaches to constitute the optimal control strategy were proposed. The dynamic operational mechanism to control agricultural non-point source pollution on watershed scale was formulated.

(5) The Analytic Hierarchy Process (AHP) was employed to establish the index system evaluating agricultural non-point source pollution in watershed. Then the current effect of agricultural non-point source pollution control in the Wuchuan watershed and the whole Jiulong River Watershed was evaluated. The Results indicated that the controls of agricultural non-point source pollution in both areas were all at lower level and that the integrated management on the watershed scale should be reinforced.

Keywords: Agricultural non-point source pollution; System control; Best Management Practices; Environmental policy

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